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REVIEWS.

PROFESSOR SPRING ON THE PHYSICS AND CHEMISTRY OF SOLIDS.

BIBLIOGRAPHY.[1]

Note préliminaire sur la propriété que possèdent les fragments des corps solides de se souder par l'action de la pression. 2^{me} série, 45, 1878, p. 746. Bull. de L'Académie Royale de Belgique.

Sur la propriété que possèdent les corps solides de se souder par l'action de la pression. 2^{me} série, 49, 1880, p. 323, *loc. cit.*

Formation de quelques arséniures métalliques par l'action de la pression. 3^{me} série, 5, 1883, p. 229, *loc. cit.*

Formation de sulfures métalliques sous l'action de la pression. 3^{me} série, 5, 1883, p. 492, *loc. cit.*

Sur l'élasticité parfaite des corps solides chimiquement définis. Analogie nouvelle entre les solides, les liquides et les gaz. 3^{me} série, 6, 1883, p. 507, *loc. cit.*

Réaction du sulfate de baryum et du carbonate de sodium sous l'influence de la pression. 3^{me} série, 10, 1885, p. 204, *loc. cit.*

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Simple observation au sujet d'un travail de M. W. Hallock intitulé : The Flow of Solids, etc. 3^{me} série, 14, 1887, p. 595, *loc. cit.*

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Über einen Fall durch Druck bewirkter chemischer Zersetzung. Zeit. f. Phys. Chem. I, p. 227.

Über die Kompression von feuchter Pulver fester Körper und die Formbildung der Gesteine. Zeits. f. Phys. Chem. 2, p. 532.

Über die chemische Einwirkung der Körper im festen Zustande. Zeit. f. Phys. Chem. 2, p. 536.

Eine Bemerkung über die Arbeit des Herrn H. Le Chatelier. Zeit. f. Phys. Chem. 9, p. 744

The prime importance to the geologist of all investigations upon the relations of matter and force at great temperatures and pressures makes it profitable, perhaps, to review the work of Walther Spring on this subject. Professor Spring is the pioneer in this field. All his conclusions and theories on the chemistry and mechanics of solid bodies are founded upon a long series of careful experiments, in the course of which he has kept substances under great pressure for periods of more than twenty years, and these furnish us almost the only trustworthy information we have on the subject. It is of especial importance to call the attention of American geologists to this work of Professor Spring, as some discredit was thrown upon his work by M. W. Hallock in a contribution published in *Bulletin 55* U. S. Geol. Survey called "The Flow of Solids, or the Behavior of Solids Under High Pressure." The critic fell into an error through a mistranslation or a misapprehension of the French language,[1] especially translating "se souder" as to melt, and through his failure to grasp the fact that there may be a molecular diffusion in substances in the solid state.

Professor Spring's development of the subject was gradual and followed the advance of his experiments, so that a chronological review of his papers will give us a good exposition of his theories. In his first paper,[2] which was preliminary, he raises the question how sedimentaries harden where there has evidently been no cementation. He states that he has been able to press perfectly dry $K\ NO_3$ and $Na\ NO_3$ under a pressure of about 20,000 atmospheres into semicrystalline masses harder than the fused substances. Two years later he contributed his first important paper on the subject,[3] which contains, besides his own valuable results, an excellent résumé of all the different theories concerning regelation. From experiments upon all kinds of chemical compounds he develops the following:

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[1] Simple observation au sujet d'un travail de M. W. Hallock intitulé: "The Flow of Solids," etc. Bull. de L'Académie Royale de Belgique. 3^me^ série, 45, 1887, p. 595.

[2] Note préliminaire sur la propriété les fragments des corps solides de se souder par l'action de la pression. Bull. de L'Académie Royale de Belgique. 2^me^ série, 45, 1878, p. 746.

[3] Sur la propriété que possèdent les corps solides de se souder par l'action de

1. All solid bodies tend to consolidate under pressure, and this tendency is a function of the malleability of the substance or, in other words, an inverse function of the internal friction.

2. Pressure aids in consolidating or welding solid bodies because it makes an intimate contact.

3. Bodies capable of assuming crystalline form tend, under pressure, to weld so that the mass has a single crystallographic orientation.

4. Welding under pressure is caused by an actual molecular diffusion in the solid state similar to that in liquids, but far less active.

5. Pressure aids diffusion merely by bringing the particles into intimate contact with each other.

6. The reactions of solids upon solids are equilibrium reactions, and therefore chemical action under pressure tends to go in the direction which gives the smaller volume. Therefore, since the crystalline state is generally that which takes the smallest volume, pressure aids crystallization.

In two succeeding articles he states that solids, as well as liquids[1] and gases, are perfectly elastic volumetrically, that is, upon removal of pressure, the molecules vibrate with the same frequency as before and so the substance assumes its former volume. The only compression he could produce was caused by the crushing in of cavities, etc., and large contraction only occurred where new chemical compounds were formed, as where a new allotropic or polymeric form of the substance was assumed. The statement that matter takes an allotropic state corresponding to the volume which it is obliged to occupy has an exact significance. Moreover, the different states of matter all belong to one series—a liquid is an allotropic form of a gas—a solid of a liquid—a denser solid of a solid of less specific gravity.

This polymerization of molecules accounts for all changes of form and the more dense the polymeric forms, in every case the less active

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la pression. Bulletins de l'Académie Royale de Belgique. 2^{me} série, 49, 1880, p. 323.

[1] Formation de sulphures métalliques sous l'action de la pression. 3^{me} série, 5, 1883, p. 492.

Sur l'élasticité parfaite des corps solides chimiquement définis. Analogie nouvelle entre les solides, les liquides et les gaz. 3^{me} série, 6, 1883, p. 507.

are they chemically. This last fact may partially explain the occurrence of chemically active substances uncombined deep within the earth. It is to be noted, however, that temperature acts in an opposite sense to pressure and for every allotropic state there may be a critical temperature above which it cannot exist no matter under what pressure.

In several following papers he explains experiments which confirm his previous conclusions on the diffusion of matter in the solid state. He finds that the velocity of diffusion depends upon three factors: (1) a constant peculiar to each substance and depending upon the velocity of molecular movements; (2) the temperature, with which the molecular velocity increases, and (3) the pressure, which makes the contact more perfect and tends to overcome the "surface tension" of the solid particles. He demonstrates that there is a critical temperature for the change of solids into liquids and mentions cases where liquids by increase of pressure have been changed into solids.[1]

In further experiments he finds that intimate contact caused by constant shaking without pressure causes diffusion between solids, and this diffusion takes place with extraordinary rapidity (three hours) at a higher temperature, though far below the melting point of either substance employed.[2]

In the article "Sur l'apparition dans l'état solide des certaines propriétés caractéristiques de l'état liquide ou gazeux des métaux,"[3] he recapitulates some of his former conclusions and presents new ones as follows:

1. Cohesion between fragments like that between drops of water must be overcome before diffusion between the two can take place.

2. The property of diffusion under pressure is not equally developed in all bodies and is best developed where internal friction is the least and where molecular velocity is the greatest.

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[1] Réaction du sulfate de baryum et du carbonate de sodium sous l'influence de la pression. Bull. de l'Académie, etc. 3^me série, 10, 1885, p. 204.

Bull. de la Société chimique de Paris, XLI, p. 488.

Sur un case de décomposition chimique produite par la pression. Bull. de 'Académie, etc. 3^me série, 13, 1887, p. 409.

Zeits. f. Phys. Chemie. I, p. 165.

Comptes rendus, t. CV, 1887, p. 165.

[2] Sur la réaction chimique des corps à l'état solide. 3^me série, 16, 1888, p. 43.

[3] Bull. de l'Académie, etc. 3^me série, 28, 1894, p. 23.

Zeit. f. Phys. Chemie.

3. Pressure alone is not so efficient as when accompanied by an agitation of the particles which breaks their cohesion and aids diffusion. This explains cold welding, etc.

4. The three states of matter are only extreme degrees of a single ne and each has a critical pressure and temperature. Solids as well as gases and liquids have faster and slower moving molecules and this variation is the most extreme where the free path is the greatest, viz., at the surface, and therefore solid bodies in contact will weld at their surfaces when below the melting point, due to the interaction of the "liquid molecules."

5. The molecular mobility of a solid body is a function of the proportion of the rapidly moving portion (liquid molecules) to the whole number of molecules.

6. Crystalline bodies have a nearly uniform rate of molecular vibration, and therefore do not "solder" at a temperature much below melting, while amorphous or partially crystalline bodies with heterogeneous molecular motions weld easily.

Finally, in the contributions of the last few years[1] he has described some of his most remarkable experiments on this subject which confirm all his former conclusions. He kept perfectly dry powdered chalk under a pressure of from 6000 to 7000 atmospheres for seventeen years and three months. This same pressure acting through a short time only makes the chalk about as hard as ordinary writing crayon, but after this long time it was found as hard as marble. The fracture was conchoidal and the microscope showed it was crystalline. The steel screw which held the chalk under pressure had completely united to the cylinder, so that the cylinder had to be cut. The chalk was of a yellow ochre color to the depth of 1½^{mm}, showing that the iron molecules had diffused 1½^{mm} into the chalk in about seventeen years.

This diffusion was at the ordinary temperature, but he has shown that at higher temperatures the velocity is much greater and " not only tends to complete the homogeneity of the solid solution, but also to cause an orientation of its molecules." These observations he applies as follows: "Les faits que j'ai observé contribueront peut-être à jeter

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[1] Bull. de l'Académie, etc., 3^{me} série, 1895. De l'influence du temps sur l'agglutination de la craie comprimée.

Sur les modifications physiques que subissent certains sulfures sous l'influence de la température. Bull. de l'Académie, 3^{me} série, 1895, p. 311.

Zeit. f. Phys. Chem.

quelque lumière sur la question de la solidification des roches dans la nature. Ils peuvent nous faire comprendre pourquoi, en général, les roches les plus solides et les plus compactes sont aussi les plus anciennes, et ils peuvent nous expliquer la présence de ces milliards de cristaux microscopiques que l'on a observés dans certaines roches, par exemple dans les phyllades, cristaux qui paraissent s'être dévéloppés même après le dépôt des alluvions nécessaires à la formation de ces masses neptuiennes."

And again: "Cette observation ne me paraît pas sans conséquence pour certaines théories pétrographiques. En effet, s'il est déja possible d'observer un changement d'état physique dans un agglomérat après onze années d'exposition à la température ordinaire, il est permis de penser que nombre de phénomènes de crystallization, voire de formation de numéraux, dans les roches agglomerées par la pression, aux dépens de matières à l'état solide, sans qu'il soit absolument nécessaire de faire entrevenir l'action de dissolvants quelconques."

He has also[1] experimented with the compression of dampened powders and finds in general that the insoluble bodies, such as metal filings, etc., do not solidify in the presence of water because the water prevents close contact. Soluble substances act differently—bodies whose solution takes less volume than the water and substance solidify more completely than in the dry state, while those whose solution is attended with an expansion of volume consolidate much better in the dry state. The explanation offered is that when the substance is more soluble under pressure, as pressure is relieved some of the material is precipitated into the interstices of the mass and it is solidified, while in the second case some of the matter is dissolved after the relief of the pressure, leaving a porous incoherent mass.

M. Le Chattilier[2] has noted this same fact that certain bodies in the presence of their saturated solutions solidify under pressure, and explains it a little more in detail as a case of equilibrium under heterogeneous pressure. The water is squeezed out of the mass and therefore is not under so great a pressure as the solid, therefore the solution next to the surface of the solid is supersaturated in respect to that farther away. This water then moving away from the solid precipitates and solidifies the rock.

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[1] Zeits. für Phys. Chem., 2, p. 532. Über die Kompression von feuchter Pulver fester Körper und die Formbildung der Gesteine.

[2] Zeits. für Phys. Chem., IX, p. 335.

It has long been known that rocks suffer actual molecular movement if the forces act so slowly that they do not overpass the elastic limit of the rock, and again bodily movement must take place if the rock is subject to stresses greater than the ultimate strength of the rock, but the knowledge of the fact that solid matter has so much in common with gases and liquids is almost wholly due to the laborious investigations of Professor Spring, and these facts should immediately take their place in our theories of the condition of matter in the interior of the earth.

C. F. Tolman, Jr.

United States Geologic Atlas, Folio 37. Downieville, California. 1897.

This folio consists of eight pages of text signed by H. W. Turner, geologist, a topographic map of the district, a map showing the areal geology, a map showing the economic features, a structure section sheet, and one page of special illustrations.

The quadrangle represented in this folio lies between parallels 39° 30′ and 40° north latitude, and 121° and 120° 30′ west longitude. It comprises a portion of the northern Sierra Nevada and lies in Plumas and Sierra counties. The area is drained by the forks of the Feather and Yuba rivers.

The formations are divided into two main groups, the bed-rock series and the superjacent series. The bed-rock series is composed of Juratrias and Palæozoic sediments and tuffs, and a series of old igneous rocks chiefly granites and porphyries. The Juratrias rocks comprise chiefly the Milton formation which is found only in the southeast portion of the quadrangle. The Milton formation, while formed of materials deposited under water, contains a large amount of igneous material. Underlying the Milton formation there are volcanic beds which are likewise presumed to be of Juratrias age, inasmuch as in the lower portion there are lenses of siliceous argillite, in one of which an ammonite was found. These volcanic beds are grouped as quartz-porphyry and as augite-porphyrite. The quartz-porphyry also occurs as dikes. The other igneous rocks forming part of the bed-rock series are granite, gabbro, and granodiorite. In the western portion of the quadrangle there are very large amounts of serpentine which have resulted from the decomposition of the pyroxene olivine rocks or peridotites and amphibolite which is the result of dynamo-metamor-